CROP PRODUCTION

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WATER-SAVING TECHNOLOGIES FOR DRIP IRRIGATION OF COTTON IN THE SOUTH OF RUSSIA

Research article

Abstract

The article presents the results of research in 2019–2020 about 4 modes of drip irrigation with maintaining of the Soil Pre-Irrigation Moisture (SPIM) 65-65-60, 70-70-65, 75-75-70, 80-80-75 % of Full Moisture Capacity (FMC), as well as 4 doses of mineral fertilizers with quantity of N70P30K23, N105P45K34, N140P60K45 and N175P75K56 kg/ha in the south of Russia. As a result of the completed field experiments, it was found that the highest yield of raw cotton of 5.33 t/ha was obtained while maintaining SPIM 75-75-70 % of FMC and applying fertilizers with doses of N175P75K56 kg/ha. The maintaining such a level of water supply and mineral nutrition made it possible to obtain the minimum values of the Water Total Consumption Coefficients (WTCC) of 46,6 mm/t and the Irrigation Water Expenses (IWE) 22.8 mm/ton, which, in comparison with other studied variants, made it possible to reduce the Total Water Consumption (Volume of Irrigation Water, Rainfalls, Soil Moisture Reserves) and the consumption of irrigation water alone to obtain 1 ton of raw cotton, respectively, up to 91,6 and 39,2 mm/ton, or up to 163,8 and 162,1%. The comparison with the control showed that drip irrigation, in comparison with furrow irrigation, made it possible to increase the yield of raw cotton by 1,.37 t/ha or 30,8%. At the same time, the total consumption of water and the consumption only of irrigation water to obtain 1 ton of raw cotton decreased by 74,8 and 76,4 mm or respectively, by 134,2 and 280,6%.

Keywords: indicators of productivity of moisture use, drip irrigation, yield of raw cotton.

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ВОДОСБЕРЕГАЮЩИЕ ТЕХНОЛОГИИ ПРИ КАПЕЛЬНОМ ОРОШЕНИИ ХЛОПЧАТНИКА НА ЮГЕ РОССИИ

Научная статья

Аннотация

В статье представлены результаты исследований, проведённых в 2019–2020 гг., в которых изучалось 4 режима капельного орошения с предполивными порогами влажности почвы 65-65-60, 70-70-65, 75-75-70, 80-80-75 % НВ на фоне 4-х доз минеральных удобрений N70P30K23, N105P45K34, N140P60K45 and N175P75K56 кг.д.в./га в условиях Юга России. Исследования позволили установить, что наибольшая биологическая урожайность хлопка-сырца 5,33 т/га получена при поддержании предполивной влажности почвы 75-75-70% НВ и внесении удобрений дозами N175P75K56. При таком уровне водообеспеченности и минерального питания были получены минимальные значения коэффициентов водопотребления 466 м^3/т и затрат оросительной воды 228 м^3/т, которые, по сравнению с другими изучаемыми вариантами, позволили снизить общий расход воды (оросительная норма, осадки, почвенные влагозапасы) и расход только оросительной воды для получения 1 тонны-сырца соответственно до 916 и 392 м^3/т или до 163,8 и 162,1 %. Сравнение с контролем показало, что капельное орошение, по сравнению с поливом по бороздам, позволило повысить урожайность хлопка-сырца на 1,37 т/га или на 30,8 %. При этом, общий расход воды и расход только оросительной воды для получения 1 тонны-сырца уменьшился соответственно на 748 и 764 м^3/т или на 134,2 и 280,6 %.

Ключевые слова: показатели продуктивности использования влаги, капельное орошение, урожайность хлопка-сырца.

1. Introduction

Drip irrigation (DR) of agricultural crops is actively developing in the south of Russia, where the largest quantity of irrigated areas in our country is concentrated. For example, at present, in the Volgograd region 50% of the arable land is irrigated with sprinkler irrigation, and the other 50% - with drip irrigation.

We have been conducting research about the cultivation of various vegetable crops with drip irrigation and sprinkling in the Volgograd State Agrarian University for more than 20 years [1].

In the conditions of import substitution, given the urgent requirement to develop Russian cotton growing in the region, 5 years ago we began to study the efficiency of these irrigation methods for irrigating cotton.

After 3 years of preliminary research in 2016-2018 [2], [3], [4], beginning from 2019, a field experiment was started to study various soil water regimes and doses of mineral fertilizers to obtain the yield of raw cotton from 3 to 5 t/ha with sprinkling and drip irrigation.

In our field experiments, for the first time in the region, one of the main research tasks was to study the possibility of water saving using drip irrigation of cotton.

The world's population is growing rapidly. For its existence, water is needed primarily for drinking and municipal water supply, industry and agriculture. However, the reserves of clean fresh water in the world are very limited.

In the condition of a sharply increasing shortage of fresh water, the issues of saving water for the production of agricultural products simultaneously with an increase the yield of agricultural crops are very actual.

Numerous studies both in Russia and abroad have shown that drip irrigation can significantly increase the yield of agricultural crops with a significant reduction of irrigation water in comparison with other irrigation methods.

In this regard, the issues of studying the possibility of reducing the consumption of irrigation water to obtain 1 ton of raw cotton occupy a significant place in the many research about growing cotton using this method of irrigation, conducted in Uzbekistan [2], [3], [4], India [5], [6], [7], China [8], [9], [10], [11], Turkey [15] and the USA [16], [17], [18].

2. Methods

The experimental site is located in the Educational Research and Production Center "Gornaya Polyana" of the Volgograd State Agrarian University. The soils of the site are light chestnut. The climate here is sharply continental with cold little snow winters and hot dry summer.

This article presents the results of studies in 2019 and 2020, which weather conditions, in relation of rainfall to the sum of average daily air temperatures, were characterized as severely arid.

The research was carried out with the cotton variety "PGSSH-1". This ultra-fast sort was created by breeders from the Volgograd State Agrarian University and the Republic of Uzbekistan especially for the soil and climatic conditions of the Volgograd region [19].

In our experiments, to obtain the yield of raw cotton from 2 to 5 t/ha, four variants of the drip irrigation regime were studied: DI -1, DI -2, DI -3, DI -4 with maintaining the Soil Pre-Irrigation Moisture respectively 65-65- 60, 70-70-65, 75-75-70 and 80-80-75% of FMC in the interphase periods "sowing - flowering", "flowering - fruit formation" and "end of fruit formation - ripening".

Simultaneously, four variants of the quantity of mineral fertilizers (QF) were investigated: the first variant (QF -1) with doses of N70P30K23; the second option (QF -2) - N105P45K34; the third option (QF -3) - N140P60K45 and the fourth option (QF -4) - N175P75K56 (kg/ha).

The control in these field experiments was the option with the traditional for Central Asia furrow irrigation, where we were maintained the same level of mineral nutrition as in the QF-4 variant (N175P75K56 kg/ha) and the irrigation regime with SPIM 75-75- 70% of FMC, the same as in the with option DI-3.

The assessment of water-saving technologies for drip irrigation of cotton was carried out according to two key indicators are commonly used to compare options in irrigation research: the Water Total Consumption Coefficients (WTCC) and the Irrigation Water Expenses (IWE).

The first indicator (WTCC) was defined as the ratio of the Total Water Consumption (Volume of Irrigation Water, Rainfalls, Soil Moisture Reserves) to the obtained yield of this crop. That is, it shows the efficiency of using the total amount of water to produce 1 ton of harvest.

To determine the second indicator (IWE), it was necessary to divide the Volume of Irrigation Water for season by the yield of raw cotton.

That is, in contrast to the WTCC, it shows how much volume only of irrigation water per season is consumed to obtain 1 ton of raw cotton, which is especially important for comparing various applied irrigation technologies and methods.

3. Results

The average yield of raw cotton for 2019–2020 is presented in the Table 1. The results of the performed research showed that the first factor that influenced on the yield of raw cotton was the drip irrigation regime.

On the options with fertilizer doses of N70P30K23 (QF-1) with an increase of the Soil Pre-Irrigation Moisture from 65-65-60 to 70-70-65% of FMC on the DI-2 option, compared to DI -1, the yield of raw cotton increased by 0,21 t/ha or 12,9%.

With an increase SPIM from 65-65-60 (DI-1) to 80-80-75% of FMC (DI-4), the increase in yield was 0,53 t/ha or 32,2%.

The highest increase of raw cotton yield was observed while maintaining the irrigation regime of 75-75-70% of FMC. Here, on the DI-3 option, in comparison with DI-1, the increase of yield reached 0,53 t/ha or 32,2%.

The similar patterns were obtained at other levels of mineral nutrition.

Our research have shown that the minimum yield of raw cotton 1,63 ... 4,30 t/ha was obtained while maintaining the soil moisture before irrigation 65-65-60% of FMC.

An increase SPIM up to 70-70-65% of FMC on the variants DI-2 contributed to obtaining the yield of raw cotton 1,84 ... 4,71 t/ha. This, in comparison with DI-1, made it possible to obtain an increase in yield 0,21 ... 0,72 t/ha or 9,7 ... 22,6%.

Higher productivity of cotton crops 2,16 ... 5,16 t/ha was observed on the DI-4 variants, where the increase in yield was 0,53 ... 1,01 t/ha or 20,1 ... 32,2%.

Our studies have shown that the second factor that influenced the yield of raw cotton was the quantity of applied mineral fertilizers.

Table 1 – Yield of the raw cotton (Y) on average for 2019–2020

Depending on the irrigation regime				Depending on the quantity of fertilizers			
Experience options	Yield, t/ha	ΔY		Experience options	Yield, t/ha	ΔY	
		t/ha	%			t/ha	%
Drip irrigation							
QF-1				DI-1			
DI-1	1,63	-	-	QF-1	1,63	-	-
DI-2	1,84	0,21	12,9	QF-2	2,50	0,87	53,1
DI-3	2,47	0,84	51,2	QF-3	3,17	1,54	94,5
DI-4	2,16	0,53	32,2	QF-4	4,30	2,67	163,5
QF -2				DI-2			
DI-1	2,50	-	-	QF-1	1,84	-	-
DI-2	2,82	0,32	12,8	QF-2	2,82	0,98	53,4
DI-3	3,23	0,74	29,5	QF-3	3,89	2,05	111,7
DI-4	3,05	0,56	22,2	QF-4	4,71	2,88	156,7
QF -3				DI-3			
DI-1	3,17	-	-	QF-1	2,47	-	-
DI-2	3,89	0,72	22,6	QF-2	3,23	0,77	31,0
DI-3	4,45	1,28	40,4	QF-3	4,45	1,99	80,5
DI-4	4,18	1,01	31,7	QF-4	5,33	2,86	116,0
QF -4				DI-4			
DI-1	4,30	-	-	QF-1	2,16	-	-
DI-2	4,71	0,41	9,7	QF-2	3,05	0,90	41,5
DI-3	5,33	1,03	24,0	QF-3	4,18	2,02	93,7
DI-4	5,16	0,87	20,1	QF-4	5,16	3,01	139,4
Furrow irrigation (FI)							
FI (DI-3, QF -3)	3,08	-1,37	-30,8	FI (DI-3, QF -3)	3,08	-1,37	-30,8

The minimum yield of raw cotton 1,63 ... 2,47 t/ha was obtained on the options QF-1 with fertilizer doses of N70P30K23.

An increase of the mineral nutrition level to N105P45K34 on the QF -2 variants contributed to the yield of 2,50 ... 3,23 t/ha. This, in comparison with QF-1, made it possible to obtain an increase in yield of 0,77 ... 0,98 t/ha or 31,0 ... 53,4%.

The higher yield of 3,17 ... 4,45 t/ha was observed on the QF-3 variants, where the increase in yield was 1,54 ... 2,05 t/ha or 80,5 ... 111,7%.

The highest yield of raw cotton of 4,30 ... 5,33 t/ha and its increase, in comparison with QF-1, by 2,67 ... 3,01 t/ha or by 116,0 ... 163,5% were obtained on the variants QF-4, where the highest level of mineral nutrition N175P75K56 was maintained.

As a result (Table 1), the highest yield of raw cotton on average for 2019–2020. equal to 5,33 t/ha was obtained on the DI-3 option with maintaining the Soil Pre-Irrigation Moisture 75-75-70% of FMC at the same time applying the highest doses of fertilizers N175P75K56, as on the QF-4 variant in our experiments.

The comparison with the control showed that the yield of raw cotton on the site with furrow irrigation was equal 3,08 t/ha, which was 1,37 t/ha or 30,8% lower than the yield of 4,45 t/ha while maintaining the third level of water availability on the variant of drip irrigation DI-3 and soil fertilization on the variant QF-3.

The Water Total Consumption Coefficients for assessing the efficiency of using moisture to obtain 1 ton of raw cotton obtained in our studies are shown in the Table 2.

The analysis of the obtained results made it possible to establish that the soil water regime was one of the main factors affecting the value of these indicators of the productivity of moisture using during the growing season of cotton.

On the QF-1 variants, with the doses of fertilizer N70P30K23, the minimum value of WTCC 100,7 mm/ton was obtained while maintaining the irrigation regime of 75-75-70% of FMC in the DI-3 variant.

A further rise of the water supply level to 80-80-75% of FMC caused the increase of water consumption to obtain 1 ton of raw cotton by 16,5 mm or 16,4%.

A decrease of the pre-irrigation soil moisture to 70-70-65 and further to 65-65-60% of FMC also increased the unproductive use of the total water consumption by 31,9 ... 46,8 mm/ton or 31,7 ... 46,4%.

The same patterns were obtained on variants with other doses of mineral fertilizers.

Thus, the results of the study showed that the lowest water consumption for obtaining 1 ton of raw cotton, 46,6 ... 100,7 mm/ton, was obtained on the DI-3 options with maintaining SPIM 75-75-70% of FMC. A rise of the pre-irrigation soil moisture to 80-80-75% of FMC caused an increase of the water consumption coefficients by 2,3 ... 16,5 mm/ton or 5,0 ... 16,4%, and a

decrease of the the pre-irrigation threshold of soil moisture to 70-70-65 and further to 65 -65-60% of FMC - by 5,0 ... 46,8 mm/ton or by 10,7 ... 46,4%.

Consequently, the drip irrigation regime of 75-75-65% HB was optimal for growing cotton in the south of Russia.

An even stronger factor influencing the productivity of moisture use in cotton crops was the level of soil fertilization.

The highest moisture consumption for obtaining 1 ton of raw cotton 100,7 ... 147,5 mm was established on the QF-1 variants with mineral fertilizer doses N70P30K23. With an increase of the mineral nutrition level to N105P45K34 on the DU-2 variants, the Water Total Consumption Coefficients decreased to 75,8… 86,3 mm/ton. A further increase in the fertilization of cotton crops to the level of N140P60K45 on the QF-3 variants contributed to a decrease WTCC to 55,8 ... 75,8 mm/ton.

Table 2 – Water Total Consumption Coefficients (WTCC) for cotton on average for 2019–2020

Depending on the irrigation regime				Depending on the quantity of fertilizers			
Experience options	WTCC, mm/ton	Δ WTCC		Experience options	WTCC, mm/ton	Δ WTCC	
		mm/ton	%			mm/ton	%
Drip irrigation							
QF-1				DI-1			
DI-1	147,5	46,8	46,4	QF-1	147,5	91,6	163,8
DI-2	132,6	31,9	31,7	QF-2	96,3	40,4	72,2
DI-3	100,7	-	-	QF-3	75,8	19,9	35,6
DI-4	117,2	16,5	16,4	QF-4	55,9	-	-
QF -2				DI-2			
DI-1	96,3	19,4	25,3	QF-1	132,6	81,0	157,0
DI-2	86,3	9,5	12,3	QF-2	86,3	34,8	67,4
DI-3	76,9	-	-	QF-3	62,5	11,0	21,2
DI-4	82,8	5,9	7,7	QF-4	51,6	-	-
QF -3				DI-3			
DI-1	75,8	20,0	35,9	QF-1	100,7	54,1	116,0
DI-2	62,5	6,8	12,1	QF-2	76,9	30,2	64,9
DI-3	55,8	-	-	QF-3	55,8	9,2	19,7
DI-4	60,5	4,7	8,4	QF-4	46,6	-	-
QF -4				DI-4			
DI-1	55,9	9,3	20,0	QF-1	117,2	68,2	139,5
DI-2	51,6	5,0	10,7	QF-2	82,8	33,9	69,2
DI-3	46,6	-	-	QF-3	60,5	11,5	23,6
DI-4	48,9	2,3	5,0	QF-4	48,9	-	-
Furrow irrigation (FI)							
FI (DI-3, QF -3)	130,6	74,8	134,2	FI (DI-3, QF -3)	130,6	74,8	134,2

The lowest values of these indicators, 46,6 ... 51,6 mm/ton were obtained on the QF-4 variants, where fertilizers were applied in doses of N175P75K56. In comparison with the variants of soil fertilization QF-3, this made it possible to reduce the water consumption for obtaining 1 ton of raw cotton by 9,2 ... 19,9 mm or by 19,7 ... 35,6%; in comparison with the QF -2 variants - by 30,2… 40,4 mm or by 64,9… 72,2%, and in comparison, with the QF -1 variants - by 54,1… 91,6 mm or by 116,0… 163,8%.

As a result, it was found (Table 2) that the lowest Water Total Consumption Coefficient, on average for 2019–2020. equal to 46,6 mm/ton, was obtained on the option with the optimal irrigation regime DI-3 with maintaining the pre-irrigation level of soil moisture 75-75-70% of FMC simultaneously with the introduction of the highest doses of fertilizers in our experiments N175P75K56, as on the option QF-4.

The maintaining such a regime of drip irrigation made it possible to reduce the total water consumption for obtaining 1 ton of raw cotton to 46,8 m or 46,4%, and the formation of such a level of mineral nutrition - to 91,6 mm or 163,8%.

The further analysis made it possible to establish that the WTCC obtained for the control option, on average for 2 years of research was equal to 130,6 mm/ton. He showed that maintaining SPIM 75-75-70% of FMC on the drip irrigation option DI-3 in combination with the level of soil fertilization N140P60K45 on the QF-3 option allowed to reduce the total water consumption for the formation of 1 ton of raw cotton by 74,8 mm or 134,2% compared to furrow irrigation.

The Irrigation Water Expenses for assessing the efficiency of using irrigation water to obtain 1 ton of raw cotton are shown in the Table 3.

The analysis of the available results made it possible to establish that the Irrigation Water Expenses in our studies changed according to the same patterns as the Water Total Consumption Coefficients.

The water regime of the soil was one of the main factors influencing the value of these key indicators of the productivity of moisture use.

The research results showed that the lowest irrigation water consumption for obtaining 1 ton of raw cotton 22,8 ... 49,1 mm/ton was obtained for DI-3 options. A rise of the pre-irrigation soil moisture to 80-80-75% of MFC caused an increase of the Irrigation Water Expenses by 2,6 ... 11,6 mm/ton or 11,4 ... 23,6%, and a decrease of the soil moisture before irrigation to 70-70-65 and further to 65-65-60% of MFC - by 0,8 ... 14,3 mm/ton or 3,6 ... 29,1%.

Therefore, the dynamics of the Irrigation Water Expenses, as well as Water Total Consumption Coefficients, proves that maintaining the water supply level at least 75-75-70% of MFC was the optimal drip irrigation regime for growing cotton on the light chestnut soil of the south of Russia.

The second factor affecting the productivity of the use of irrigation water in cotton crops was the level of soil fertilization.

The highest costs of irrigation water for obtaining 1 ton of raw cotton 49,1 ... 63,3 mm were established on the QF-1 variants with the quantity of fertilizers N70P30K23. With an increase of the mineral nutrition level up to N105P45K34 on the QF-2 variants IWE decreased to 37,4 ... 42,8 mm/ton. Further improvement of the fertilization of cotton crops to the level of N140P60K45 on the QF-3 variants helped to reduce the consumption of irrigation water to 27,2 ... 32,6 mm/ton.

The lowest values of these indicators 22,8 ... 25,3 mm/ton, were obtained on the QF-4 variants, where fertilizers were applied in doses of N175P75K56. In comparison with QF -3 variants of soil fertilization, this made it possible to reduce the Irrigation Water Expenses to obtain 1 ton of raw cotton by 4,5 ... 8,4 mm or 19,7 ... 34,9%; in comparison with the QF -2 variants - by 14,7 ... 17,5 mm or 64,4 ... 71,5%, and in comparison, with the QF -1 variants - by 26,3 ... 39,2 mm or 115,6 ... 162,1%.

Table 3 – Irrigation Water Expenses (IWE) for cotton on average for 2019–2020

Depending on the irrigation regime				Depending on the quantity of fertilizers			
Experience options	IWE, mm/ton	Δ IWE		Experience options	IWE, mm/ton	Δ IWE	
		mm/ton	%			mm/ton	%
Drip irrigation							
QF-1				DI-1			
DI-1	63,3	14,3	29,1	QF-1	63,3	39,2	162,1
DI-2	60,1	11,1	22,6	QF-2	41,4	17,3	71,5
DI-3	49,1	-	-	QF-3	32,6	8,4	34,9
DI-4	60,6	11,6	23,6	QF-4	24,2	-	-
QF-2				DI-2			
DI-1	41,4	4,0	10,8	QF-1	60,1	36,6	155,2
DI-2	39,3	1,9	5,0	QF-2	39,3	15,7	66,7
DI-3	37,4	-	-	QF-3	28,5	4,9	20,9
DI-4	42,8	5,4	14,5	QF-4	23,6	-	-
QF-3				DI-3			
DI-1	32,6	5,4	19,7	QF-1	49,1	26,3	115,6
DI-2	28,5	1,3	4,7	QF-2	37,4	14,7	64,4
DI-3	27,2	-	-	QF-3	27,2	4,5	19,7
DI-4	31,3	4,1	15,1	QF-4	22,8	-	-
QF-4				DI-4			
DI-1	24,2	1,4	6,2	QF-1	60,6	350,3	139,2
DI-2	23,6	0,8	3,6	QF-2	42,8	17,5	68,9
DI-3	22,8	-	-	QF-3	31,3	6,0	23,7
DI-4	25,3	2,6	11,4	QF-4	25,3	-	-
Furrow irrigation (FI)							
FI (DI-3, QF -3)	103,7	76,4	280,6	FI (DI-3, QF -3)	103,7	76,4	280,6

Thus, our studies have shown that the lowest costs of irrigation water, on average for 2019–2020. equal to 228 m3/t, were obtained on the DI-3 option with maintaining the pre-irrigation moisture threshold of 75-75-70% HB simultaneously with the application of the highest doses of fertilizers N175P75K56, as on the QF-4 option.

Maintaining such a regime of drip irrigation made it possible to reduce the consumption of irrigation water for obtaining 1 ton of raw cotton to 14,3 mm or to 29,1%, and the formation of such a level of mineral nutrition - to 39,2 mm or 162,1%.

The further analysis (Table 3) made it possible to establish that, on the control variant, the Irrigation Water Expenses were obtained, on average for 2 years of research equal to 103,7 mm/ton.

So, it was found that maintaining the pre-irrigation soil moisture of 75-75-70% of FMC using the drip irrigation in combination with soil fertilization N140P60K45 can reduce the irrigation water consumption for the formation of 1 ton of raw cotton by 76,4 mm or by 280,6% in comparison with furrow irrigation.

To maintain such a regime of drip irrigation, it was carried out 1 post-sowing irrigation with a rate of 13,0 mm/ha and 2...3 irrigations of 16,0 mm/ha in the period from sowing to flowering and else 2 ... 3 irrigations with a rate of 16,0 mm/ha in the period from flowering to fruit formation and of 1 ... 2 irrigations of 19,0 mm/ha in the period from the end of fruit formation to ripening.

4. Conclusion

As a result of the conducted field experiments, it was found that the highest yield of raw cotton of 5,33 t/ha on the light chestnut soil of the south of Russia was obtained while maintaining the pre-irrigation soil moisture of 75-75-70% of FMC and applying fertilizers with doses of N175P75K56.

Maintaining this level of water supply and mineral nutrition made it possible to obtain the minimum values of the Water Total Consumption Coefficient 46,6 mm/ton and the Irrigation Water Expenses 22,8 mm/t, which, in comparison with other

studied options, made it possible to reduce the total water consumption (irrigation rate, precipitation, soil moisture reserves) and the consumption only of irrigation water to obtain 1 ton of raw cotton, respectively, up to 91,6 and 39,2 mm or up to 163,8 and 162,1%.

Comparison with the control showed that drip irrigation, in comparison with furrow irrigation, made it possible to increase the yield of raw cotton by 1,37 t/ha or 30,8%. At the same time, the total water consumption and the consumption of only irrigation water to obtain 1 ton of raw cotton l decreased by 74,8 and 76,4 mm, or by 134,2 and 280,6%, respectively.

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Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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